National
Engineering
Policy Centre

Royal Academy
of Engineering

Smart Systems for Clean Power

Why faster, better digitalisation is critical to Clean Power 2030 and beyond

Contents

Foreword

The energy system of the near future will be vastly more complex than what has gone before. In the past the system was dominated by a small number of large power plants, but the system we are moving to will source power from a myriad of places, from rooftop solar panels to wind turbines in the North Sea as well as nuclear generators, serving a complex landscape of electric vehicles, heat pumps and electrified industrial plants. Power will move in multiple directions at once, changing dynamically in response to factors as diverse as weather conditions and the behaviours of millions of energy users.

Huge effort is going into new energy generation, transmission and distribution infrastructure, but making the future system work as a whole is just as important in meeting society's needs for affordable, reliable electricity and all that this underpins in terms of growth, innovation and productivity. Such a system must be digitally enabled, with exchange of data, supported by appropriate software and hardware, helping system and network operators to see across the system in real time and co-ordinate rapid action to manage it. Realising such a digitalised system will require a robust engineering delivery approach focussed on the management of related risks and attention to system integration.

Many of the biggest risks around the transformation lie in the ability to connect and integrate the many component parts efficiently and effectively, and those risks are rising. Before coming to them, it is important to acknowledge what is going well, much of which we called for in our report of 2024 – Rapid Decarbonisation of the GB Electricity System. The establishment of a dedicated Clean Power Unit within the Department of Energy Security and Net Zero was a good start, as was focused attention on connections reform by Ofgem and the National Electricity System Operator (NESO), procurement rounds for new generation, and rapid progress on the Planning and Infrastructure Bill. The focus on ensuring that local distribution network capacity stays ahead of the curve has come with anticipatory investment, and GB Energy is a welcome addition to the landscape with its role in driving innovation, manufacturing, supply chains and investments in enabling infrastructure.

For all this, however, there are most definitely areas in which insufficient progress is being made: these include rolling out consumer-led flex, integration of a distributed system at the point of delivery, development of deployable Long Duration Energy Storage technologies and addressing the short-, medium- and long-term skills challenges.

The daily reality for the UK's businesses and consumers is that electricity prices are simply far too high, and government has announced rapid measures to address, in part, the impact of global events on UK's gas-reliant power system and industrial and domestic heating.[i] A deeper worry is that if the pace of digitalisation remains insufficient, and if we continue to lack the coordination and strategic oversight needed to deliver true systems integration, we risk locking ourselves into a system which costs more to build, is less reliable, and results in higher bills than necessary.

A digitally enabled system

This report deals with the first of these challenges. In it we set out the case for the critical role and urgency of digitalisation in enabling Clean Power 2030 and the further changes that will be needed beyond that target. We have illustrated this with specific use cases and made recommendations for the architectural coordination needed for accelerated and successful delivery.

Digitalisation is a key enabler of consumer-led flex, using digital technology to automate households' use and purchase of electricity to buy it when it is cheaper and greener, giving them greater ownership of their energy use and reduced bills without inconvenience or effort. It can also bring system-level reductions in cost as well as improved efficiencies through visibility of assets on the system and enhanced data to support effective planning for network upgrade investment. If, in light of the recent energy shock, government is seeking to go further and faster on their clean power mission, they must go further and faster on digitalisation as an underpinning enabler of the system we need to achieve. But the pace of digitalisation is insufficient and accountability within Government is unclear.

Delivery, affordability and risk

Successful delivery of systems transformations such as decarbonisation of the electricity system requires us to actively manage and minimise delivery risk. This means ensuring effective systems integration, which itself is vital to the resilience and reliability of the system both as it transitions, and to ensure the resulting system is interoperable and functioning at the point of delivery. Engineers do this every day, and this engineering discipline must be built into the government's delivery of Clean Power 2030: setting clear project outcomes, effective management of project connection dates including risk of delays and effective accountability, active management of programme risk, and active, adaptable management of interfaces and interdependencies. Engineering project experience shows that effective management and mitigation of delivery risk will also ensure system upgrade and build out is delivered at lowest cost.

The next phase of our work will therefore utilise the engineering profession's immense expertise in complex project delivery and complex systems integration to advise government on lessons from across infrastructure sectors with case studies and recommendations on managing and minimising delivery risks and costs specifically relevant to the clean power challenge. We will focus on where effective systems integration matters most and where its absence puts delivery of clean, secure/resilient and affordable electricity at risk.

What is needed from here

We have two clear asks for government. First, based on the case set out in this report, to increase the pace and urgency with which we digitalise our electricity system. Second, to work with the engineering profession to learn from past experiences of mega project delivery and embed the lessons, practices and capabilities needed to give this system transformation the best chance of success. The good news is that these are precisely the kinds of challenge the NEPC was established to help with and we are here to do so.

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i. Such as the package of measures announced by the Secretary of State on 21 April 2026.

Executive summary

Key messages

- **Digitalisation is essential for delivering Clean Power 2030; digitalisation must accelerate rapidly to avoid jeopardising both 2030 and 2050 goals.**
- **Consumer-led flexibility (CLF) is mission-critical, and digitalisation is a critical enabler of CLF.**
- **Digitalisation enables smarter tariffs, reduced bills, and consumer engagement that builds political legitimacy for the transition.**
- **Digitalisation is essential to facilitate the rapid electrification of heat and transport expected post-2030.**
- **Digitalisation increases efficiency and system resilience and reduces system costs, including curtailment, if the system is effectively coordinated.**
- **Developing an architecture and roadmap is essential to making rapid progress in this area.**
- **Policy oversight of all aspects of digitalisation must be clarified with clear lines of oversight by central government. This should include a clear decision on who holds architectural responsibility and the establishment of a permanent digitalisation coordination function.**

Digitalisation is **mission critical** to delivering the UK's Clean Power 2030 (CP2030) target and preparing the energy system for the rapid electrification of industry, heat, and transport expected throughout the 2030s. The current pace of digitalisation is **insufficient**, and the slow progress in developing a coordinated system architecture risks delayed delivery, rising costs, missed opportunities for better system design and operation, and a system unfit for the future.

A highly decentralised, renewables-led, and flexible electricity system requires real-time operational visibility of data and assets, automated flexibility, an efficient and well-functioning power market, rapid data sharing between all users, and coordinated management of millions of distributed assets. Digitalisation is the 'act of using digital technologies to change the way a system operates, with the goal of increasing efficiency, supporting decision making and unlocking new value and opportunities'.[1] While this definition and others focus on technologies and their uptake, it is important to stress that the wider process of digitalisation extends beyond technology to involve people and processes; this includes their decision-making and behaviours within the energy system – across organisations, communities, and individual households.

This report focuses on the critical aspects of digitalisation needed to achieve the CP2030 target and the benefits particularly relevant to this timeframe. The benefits of digitalisation go far beyond CP2030, and several are referred to in the report, but this is not exhaustive. Similarly, this report does not cover aspects of the clean power transition that digitalisation does not contribute to addressing, neither does it provide an in-depth examination of potential strategies to educate and inform consumers on the transition to a digitalised system, which will be critical to success.

The value case for digitalisation

Digitalisation enables:

- **Consumer-led flexibility (CLF)**, a core pillar of CP2030's ambitions. According to modelling by the National Energy System Operator (NESO), CLF must rise from 2.5 gigawatts (GW) to 10–12 GW by 2030 to achieve the CP2030 target, maintain stability, reduce reliance on gas generation, and mitigate risks from the pace of grid buildout, both from constraints on the transmission and distribution networks and from supply chain constraints.[2,3]
- **Electrification of heat and transport**, with demand expected to grow by 19 terawatt-hours (TWh) annually into the 2030s (more than 7% of current annual demand), across millions of new distributed assets.[2] Digitalisation will be essential for managing the resulting stress on distribution networks, providing the data to improve network operability, making optimal investment decisions for network upgrades, and enabling consumer participation in flexibility markets.

Digitalisation unlocks system efficiencies, cost savings, and consumer benefits:

- **Reduced system costs** through dynamic system management, reduced curtailment, and optimised use of renewable generation via demand turn up. Annual curtailment costs reached £1.5 billion in 2025 and could rise to £8 billion by 2030.[4,5] Digital solutions that support optimised flexibility and introduce more innovative 'demand turn up' products (means of encouraging consumers to increase their usage when energy is plentiful) are one of several options to counter these rising curtailment costs. By maximising CLF, enabled by digitalisation, the profits currently generated from high system balancing costs from fossil fuel generation can be redistributed to homes and businesses that have the assets to provide flexibility to help balance the grid.
- **Lower consumer bills** through smart tariffs and automated participation in flexibility services. Electric vehicle (EV) owners and heat pump households already save between £250 and £330 annually via time-of-use optimisation.[6,7] This could be improved through access to more dynamic tariffs and demand turn up potential. Optimal use of networks and other assets will reduce the need for investment in their reinforcement, further lowering consumer bills through the price control mechanism.
- **A more resilient system**, less dependent on wholesale gas price volatility due to renewables, improved management of peak demands, and better adaptability to localised or national disruptions through visibility of granular asset data and coordinated asset control.
- **Enhanced planning and operational efficiency** via digital twins, AI-enabled decision-making for targeted maintenance, and improved visibility of network constraints, which can deliver billions in savings and support efficient sequencing of low-voltage network reinforcement.[8]
- Real-time operation by **control rooms** of a distributed system at high temporal resolution, enabling resource optimisation and efficient response in a dynamic system.

Without rapid digitalisation, the Great British (GB) electricity system faces several risks:

- **Failure to deliver CP2030**, as the system struggles to reach the capacity, flexibility, and emissions goals of CP2030.
- **Higher consumer bills**, as smart tariffs, automation, and dynamic asset usage will not scale.
- **A lack of consumer trust** as the consumer offer and experience grows in complexity rather than being simplified, reducing the political mandate for the transition.
- **Rising system costs**, due to inefficiency, increased need for investment, low innovation from a lack of access to quality, granular data and an inability to dynamically manage capacity or reduce curtailment.
- **Insufficient consumer-led flexibility**, as flexibility cannot be automated and assets struggle to connect, share real-time data, or coordinate turn up and turn down events.
- **Continued vulnerability** to global price shocks due to ongoing reliance on gas that could otherwise be reduced faster.
- A system that cannot handle the expected increase in electrified demand, potentially **derailing efforts to electrify heat and transport.**
- **A fragmented system**, plagued by duplication, inefficiency, and poor interoperability.
- **Increased operational risks** as the system becomes too complex to operate without real-time digital visibility.

Digitalisation as the enabler of consumer-led flexibility

Achieving CP2030's flexibility target requires:

- **Smart meter rollout completion and upgrades:** smart meters at the point of use provide crucial data on energy usage. Penetration needs to increase from 70% to 86–90%, while seven million smart meters require upgrades due to lack of functionality and the 2G/3G switch off by 2033 at the latest.[9–11]
- **Market-wide Half-Hourly Settlement (MHHS):** successful and timely delivery of MHHS is needed to enable real-time tariff innovation, improve data visibility, and unlock between £1.6 billion and £4.5 billion in net savings by 2045.[12]
- **Interoperability, defined standards, and data sharing:** this is critical for smart EV charging, 'vehicle-to-everything' (V2X, this includes both 'vehicle-to-grid' and 'vehicle-to-house') technology, peak shifting via heat pump use, and coordination across millions of smart domestic, commercial, and industrial assets. Today, fragmentation in interoperability between smart meters, EVs, charge points, and suppliers, and a lack of data sharing between equipment, prevents largescale dynamic electricity use.
- **Widespread automation of consumer flexible assets:** evidence from the Crowdflex trial shows that automated tools improve demand shifting by 30%.

The need for a digitalisation coordination function

At present, there is no designated body who has overall responsibility and ownership of architectural governance and coordination of a nationwide digitalisation strategy. The result is fragmented efforts, duplicated activity, technical divergence across the system, slow progress towards agile and flexible energy systems and confusion for industry participants about where to direct conversations and efforts. This lack of clarity and direction has impeded progress towards CP2030 and risks the delivery of systems that fail to integrate. The Department for Energy Security and Net Zero (DESNZ) and Ofgem have made a good step forward in the Energy Digitalisation Framework by assigning domain coordinator roles to multiple accountable parties, and in setting out the pathway to establishing a coordination function, but this is moving too slowly.[13]

While some aspects of digitalisation may naturally emerge via the market, this will not occur with the necessary pace or level of coherence and coordination needed to rapidly and efficiently decarbonise the electricity system. Without strategic oversight of digitalisation, there is no guarantee that the desired outcomes will be achieved, and certainly not without substantial and unquantifiable risk and excess cost. Strategic oversight will need to include consideration of incentives to participate for both the regulated and non-regulated sectors that will be key to effective delivery. Careful thought will be needed on the scope of the socio-behavioural changes and the incentives needed for Ofgem-regulated organisations and non-regulated entities to participate in rapid digitalisation and a fully digitalised system.

An effective coordination function and system architecture is essential to:

- Define use cases, rules, standards, and interfaces where appropriate in the system;
- Ensure interoperability where needed and prevent technical lock-in;
- Align delivery timelines and functional dependencies;
- Provide a reference framework for innovators and delivery bodies;
- Support whole system alignment across data sharing, cybersecurity, and market design.

Options include hosting the coordination function within NESO, creating an independent entity, or adopting a federated model. Each has trade-offs, but we stress that central coordination must be established urgently to avoid jeopardising CP2030 and the long-term electrification pathway. It is important that timelines for the establishment of a permanent coordination function, digitalisation architecture, and comprehensive delivery plan are not permitted to drift. The DESNZ Energy Digitalisation Framework states that the process of setting up the permanent coordination function will take betwen two to three years, thus potentially taking until 2029.[13] This slow pace is concerning, as is the lack of committed timelines beyond the end of the calendar year.

Recommendations

The government should prioritise digitalisation as a matter of urgency. Specifically, it should:

Urgently establish a permanent **digitalisation coordination function** as envisaged in the recently published Energy Digitalisation Framework. The government should confirm that the architecture to be prepared within the digitalisation coordination function will be supported by a digitalisation landscape and roadmap.

Ensure that the digitalisation coordination function has the **capability to ensure delivery** of systems and solutions that conform to the architecture, and mitigate risk, acknowledging that many parties will contribute to delivery. These parties will include those providing shared infrastructure and those providing innovative competitive services.

Establish a **system integration function**, that works closely with, or as part of, the digitalisation coordination function to ensure that systems and solutions work across the evolving energy system.

Clarify policy ownership for all aspects of digitalisation and establish dedicated **oversight** for each issue **within central government.**

Implement **feedback loops** that inform and enable change. Continuously monitor, capture, and learn from real time activity and explicitly feed this learning into improvement and evolution measures for all parties.

Use NESO's **Sector Digitalisation Plan** as a basis for near-term actions and identification of gaps in oversight and delivery.[1] This document is a good starting point, but the actions and focus areas identified need to be actively managed if they are to be useful.

1. Introduction

The Great British (GB) electricity system is undergoing a profound, system-wide transformation as it transitions from the historical fossil fuel-powered system to one centred on more intermittent renewable energy generation where sources of generation, demand, and flexibility are distributed across the system. The UK government has made a commitment to deliver the Clean Power 2030 vision in which 95% of Great Britain's energy generation in 2030 will come from clean sources, with a reduced carbon intensity of 50 gCO_2e/kWh compared to 171 gCO_2e/kWh in 2023.[3] This is an immense challenge that will require whole-system thinking, strong leadership, and clear mechanisms for delivery, including an ambitious plan for digitalisation.

Digitalisation, as described by NESO, is the 'act of using digital technologies to change the way a system operates, with the goal of increasing efficiency, supporting decision making and unlocking new value and opportunities'.[1] While this definition and others focus on technologies and their uptake, it is important to stress that the wider process of digitalisation extends beyond technology to involve people and processes; this includes their decision-making and behaviours within the energy system – across organisations, communities, and individual households.

Digitalisation is not an end-goal in itself; it is a critical enabler for the clean power transition in which the system will become increasingly decentralised and complex. Without rapid progress on digitalisation – involving a clear and coordinated plan, backed by clear leadership – the decarbonisation of the GB electricity system will become significantly more difficult and costly. Digitalisation has been naturally developing in the energy sector for decades through market implementation of computing and more widespread use of data. As the energy system transforms, the digital capabilities that support it must transform too. If left purely to the market, there is increased risk of duplication, higher costs, slower progress, and an overall lack of coordination across the system; digitalisation must co-evolve with the wider energy system to ensure that crucial components are not overlooked or fail to integrate.

In its 2024 report on the 'Rapid decarbonisation of the GB electricity system', the National Engineering Policy Centre (NEPC) set out the critical need for strategic digitalisation to be embedded throughout the system. The report made two recommendations to the government in relation to digitalisation. These were to:

- *Establish a 'digital architect', ideally in NESO, responsible for developing digitalisation strategy and architecture, and a roadmap that aligns with and shapes the emerging plans for the energy system (Recommendation 10), and to:*
- *Establish a dedicated digitalisation delivery unit to drive integration of this roadmap into delivery of the new energy system, working with the digital architect to deliver an initial delivery plan (Recommendation 11).*[14]

The report was published in July 2024 and to date, progress on both recommendations has been slow or not yet started. In their 2025 report, the National Infrastructure Commission recommended:

"Going further and faster on digitalising the network and deploying flexibility in a way that maximises national benefits for the electricity system and for consumers" [15]

Recent publications such as the Clean Flexibility Roadmap, the Warm Homes Plan, and NESO's Sector Digitalisation Plan have highlighted the importance of digitalisation.[1,6,16] NESO are also working to develop a Data Sharing Infrastructure to enable the energy sector to share data and models in a scalable, secure, and resilient way.[17] Beyond NESO, there are also other delivery bodies working in this space. The Retail Energy Code Company (RECCo) has been appointed to deliver the consumer consent service and is also supporting the Smart Secure Electricity Systems programme to deliver tariff interoperability arrangements. Elexon is the market facilitator and is the operator and delivery body for the Flexibility Market Asset Register (FMAR). The aim of this work is to provide a single, standardised system for registering flexibility assets across national and local markets. Elexon has also been assigned as responsible organisation for behind-the-meter asset data and, provisionally, domain coordinator for metering asset data. Both data domains will be critical for delivery of consumer-led flexibility.[13]

Ofgem published an open letter in November 2025 on 'Energy Digitalisation Governance: architectural coordination' which sought views on the need, constituent elements, and function of architectural coordination. We are pleased to see the publication of the letter, and an overview of the NEPC response is set out in Section 4, outlining our recommendations for architectural coordination in this context and how we envision this working in practice. The release of the 'Energy Digitalisation Framework' in March 2026 (and its proposed permanent coordination function) is a welcome step but given the Clean Power Action Plan was published in December 2024 and fewer than four years remain until the target deadline of the end of 2030, progress is moving too slowly. NESO has been given the task of preparing an initial system architecture by August 2026, which is an important step forward but as yet, a permanent coordination function (architect) and a digitalisation delivery unit with a clear remit to drive progress in this area have not been established.[6,13] While the Energy Digitalisation Framework demonstrates admirable ambition, greater clarity on the pathway to achieve this vision is still required to translate this ambition into reality.[13]

In light of the limited progress, this report sets out the critical role of digitalisation in delivering the Clean Power target and in preparing the system for the oncoming electrification of heat and transport in the 2030s that is expected. It builds on the recommendations of the 2024 NEPC report and lays out the value case for digitalisation, particularly in relation to its role as a critical enabler of consumer-led flexibility, which has a sub-target of 10 to 12 GW in the Clean Power Action Plan.[3]

We are pleased to see the government's recognition of the importance of consumer-led flexibility and welcomed the appointment of a dedicated Flexibility Commissioner to the Clean Power 2030 Advisory Commission.[6]

While there is currently a significant focus on the Clean Power 2030 target, including in this report, for the full whole-system efficiencies and consumer benefits to be realised, digitalisation will need to be a cross-vector, whole system enabler of a functioning energy system beyond 2030. It is worth stressing upfront, therefore, that the aspects of digitalisation discussed in this report (such as secure data sharing, asset registration, and consumer consent) apply across the whole energy system including gas-fired and hybrid assets.

Beyond the energy sector, there are also significant developments in digitalisation that are enabling progress across a range of industries.
The 2025 Industrial Strategy recommended the development of activities such as the National Data Library and Data Sharing Infrastructure Initiatives.[18]
The Department for Business and Trade (DBT) are also working on smart data governance models for which the energy sector is one of the key areas of focus. There is also much historical work in both DBT and, before that, the Department for Business, Energy, and Industrial Strategy (BEIS) on the development of connected digital twins and various sectors (water, road, rail, agri-food) are undergoing digitalisation journeys.[19,20]
Interoperability of energy sector initiatives with these activities and wider sectors would be beneficial to seamless integration across sectors.

Air source heat pumps installed in an urban setting.
Photo: Shutterstock

2. Digitalisation as a critical enabler of consumer-led flexibility

2.1. The need for consumer-led flexibility

Consumer-led flexibility is essential to:

- **Improve system resilience and maintain system stability in an increasingly complex and distributed energy system, including reducing peaks in demand for generation;**
- **Reduce costs for consumers;**
- **Manage the increased demand for electricity from heat and transport;**
- **Mitigate the risk of delivery failure in other parts of the system.**

Balancing the system

Flexibility has always been a central component of the electricity system; it simply refers to the system's ability to balance the supply and demand of electricity in all parts of the network. Historically, this flexibility has been provided by dispatchable fossil fuel generation, but this role will reduce as the UK transitions towards a decarbonised economy and energy system.[21] The amount of battery assets on the system is already contributing to significant savings in carbon emissions; in 2023, battery energy storage in Great Britain saved 950,000 tonnes of carbon through participation in frequency response services meaning that NESO requires fewer carbon-emitting combined cycle gas turbines (CCGTs) to provide inertia to the grid.[22] NESO decided to reduce instructions to CCGTs for inertia management on account of the success of batteries in stabilising grid frequency; this was originally set to increase by up to 50% in 2024.[22]

The future system will be substantially more consumer-led and more decentralised with millions of assets, particularly on the low voltage (LV) distribution network, which distributes electricity to most homes and businesses. Flexibility at this consumer level will be increasingly important to help manage peak demand and capacity as we move to a more intermittent, renewable generation-led and electrified system.

Consumer-led flexibility (CLF) refers to consumers adjusting their electricity use – via the participation of smart appliances and technologies in flexibility markets – to periods when energy is more abundant, reducing the demand on the network, particularly at peak times.[6] These actions are generally driven by price signals that incentivise electricity use away from peak times, thereby reducing energy costs for consumers. This is enabled by novel tariff offers by energy suppliers. In addition to CLF in domestic dwellings, there are numerous small commercial and industrial buildings that can flex their demand and participate in CLF.

In their 2025 report, the International Energy Agency highlighted the value of demand flexibility (another term for CLF) and how it can increase system efficiency by up to 30%.[23] As part of their broader recommendations to reduce constraint costs, LCP Delta highlighted the need to increase participation of smaller assets in the balancing mechanism, and to implement forward contracts for flexible capacity outside the balancing mechanism to help reduce redispatch actions.[24]

The Clean Power 2030 (CP2030) Action Plan outlines a goal of 10 to 12 GW of CLF by 2030.[3] At the time of the Action Plan's publication, the figure achieved so far sat at 2.5 GW.[2] Crucially, this target is for delivered flexibility; a higher amount of available flexibility is needed at any given time to ensure this target is consistently met. Therefore, to meet the goal outlined in the Action Plan, the available CLF across the system will need to at least quadruple in the next four years, according to the NESO Clean Power pathways.[2] Without adequate CLF in the system, greater network capacity, particularly in the distribution network, and therefore investment, will be needed to meet peak demand. This will incur higher costs for the networks and ultimately consumers. In the context of the clean power mission, a key aim of which is to minimise the amount of gas-fired electricity in the system, failing to meet the CLF target would likely result in more gas-fired power on the system.

Consumer bill reduction

While it is important to remember that consumers do not always act as rational economic actors, meaning non-economic incentives need to be considered when aiming to scale up use of CLF, perhaps the strongest argument for CLF is its ability to directly deliver bill reductions to consumers. Savings are already possible for end-users; DESNZ analysis indicates that owners of electric vehicles (EVs) can save £330 annually by shifting to overnight charging while households with heat pumps can save more than £250 annually by switching to a time-of-use (TOU) tariff and moving usage away from peak times.[6,7] However, much of the existing utilisation of CLF is through fixed TOU tariffs and relies on public awareness of the options and benefits; the potential savings from a more intelligent system that optimises the use of dynamic smart charging of EVs across the network could be much greater. Truly dynamic tariffs could be utilised to supress the peak during periods of high demand as well as turn up demand during periods of excess generation which would minimise curtailment costs. Furthermore, engaging consumers in the clean power transition through participation in flexible tariffs should contribute to building a public mandate for decarbonisation that will support future policy strategy. This political salience emphasises the need for CLF.

National Grid electricity transmission lines and pylons with wind turbines in Heysham, Lancashire, UK.
Photo: Alamy

Deployment of CLF is expected to help reduce overall system costs, with early modelling finding that short-term flexibility (of which, CLF is a significant component) could reduce system costs by between £30 billion and £70 billion between 2020 and 2050.[25] CLF can deliver significant system value through better utilisation of assets, thus avoiding asset oversizing. The savings from this can be distributed throughout the value chain. By maximising CLF, enabled by digitalisation, the profits currently generated from high system balancing costs from fossil fuel generation can be redistributed to homes and businesses that have the assets to provide flexibility to help balance the grid.

A 2025 report by the National Infrastructure Commission (NIC, now NISTA) calculated the cumulative expenditure required on the distribution networks under a 'high flexibility' scenario compared to a 'low flexibility' scenario system. Their 'high flexibility' scenario includes assumptions around consumer actions based on price signals and mechanisms such as TOU tariffs, demand side response, and smart meter-based tariff innovations. They found high flexibility resulted in investment savings of between £1.5 billion and £2.8 billion by 2030, depending on the levels of flexible operation of EVs, heating technologies, and energy storage.[15] As the total number of EV assets remains static across scenarios, with flexibility driven by the proportion of different charging types, it is possible to conclude that potential savings would be significantly reduced if EV uptake is lower or delayed, with similar consequences for reduced uptake of other low carbon technologies with flexibility potential. The NIC estimates were based on NESO's Future Energy Scenarios (FES) 2023 with assumptions about consumer-led flexibility built directly into the load profiles of the model, whereas the CP2030 targets for CLF are based upon FES 2024, among other modelling differences. Therefore, while these estimates cannot be directly compared to the CP2030 CLF target, they are a strong indicator of the potential cost savings that CLF can achieve.

Risk mitigation

The existence of a diverse portfolio of domestic assets and CLF acts as a mitigator against the risk of delivery failure in other parts of the system. For example, if efforts to extend and upgrade the national transmission network are limited by pressure on already delayed supply chains.[26] The delivery of all planned generation projects is similarly at risk from increased supply chain and construction costs, which contributed to the decision in May 2025 to cancel the Hornsea 4 offshore wind project.[27] The ongoing delays within the grid connection queue are another major risk to delivery of CP2030. Maximising the gigawatts delivered by CLF on the distribution network will reduce exposure to risk of CP2030 target failure should other aspects of the system, such as those outlined above, fail to deliver. Moreover, the maintenance of LV networks broadly relies on a different skilled workforce than those that build and maintain larger assets such as transmission infrastructure. This added diversity is an important risk mitigation for the CP2030 programme as it helps ease a skills pinch at the transmission level. In short, all CLF achieved contributes to the realisation of the goal of decarbonisation while all CLF left unachieved adds risk and cost.

A system fit for the future

CLF will be crucial beyond 2030. The urgency to meet the CP2030 target and to lessen the UK's dependency on imported gas is undoubtedly a hugely significant political and engineering challenge, but the clean energy transition will not stop at 2030. Through the 2030s and beyond, decarbonisation pathways require the pace of electrification to accelerate and its extent to grow, primarily driven by increased uptake of EVs and heat pumps as we decarbonise transport and heating. This is expected to equate to an increase of 19 TWh of electricity demand per year, on top of a baseline demand of 258 TWh in 2023.[2] The system at 2030 needs to be ready for this expected growth.

It is important to remember that 2030 is an intermediate checkpoint on the way to a 2050 net zero economy and the sprint to CP2030 should not put the 2050 targets at risk by building a system that is not fit for future purpose. CLF needs to be embedded into the system ahead of this rise in demand to ensure that progress towards decarbonisation of heating and transport does not stall through, for example, a lack of interoperability of technology, and access to dynamic consumer tariffs.

EV charging being managed via smartphone.
Photo: Shutterstock

2.2 How digitalisation enables consumer-led flexibility

A highly decentralised, renewables-led electricity system requires real-time operational visibility, automated flexibility, and coordinated management of millions of distributed assets. Digitalisation enables CLF by:

- **Maximising flexibility through automation and data-driven decision making;**
- **Maximising the potential of turn down and turn up events, reducing curtailment costs;**
- **Ensuring connectivity and communication between the system and individual assets.**

Consumer empowerment

"Effortless participation in demand flexibility through digitalisation and automation is likely to be the path to the highest and most effective levels of responsiveness" [2]
NESO, 2024

The effectiveness, system benefits, and cost-savings of CLF are maximised when it is automated, coordinated, and intelligent; this requires digitalisation. The most recent findings from the Crowdflex trial indicate that automation is key to scaling CLF, with automated digital solutions helping participants shift 30% more electricity over 400 turn up and turn down events.[28,29] Beyond financial incentives, the trial also found that behaviour change was partly driven by habit and ease, highlighting the need for smart, digitally interoperable systems to sustain uptake of CLF amongst consumers. Currently, just 1.5% of residential peak demand responds to innovative tariffs or centrally-dispatched signals to customers; this needs to increase to 8-9% to achieve the CP2030 targets.[2] In their advice on achieving CP2030, NESO highlight the need to empower domestic, commercial, and industrial consumers to participate in CLF and both a higher uptake of innovative tariffs and automated scheduling of smart appliances will be needed to achieve this.[2]

To successfully maximise CLF, a significant boost in the rollout of smart meters will be required. Domestic uptake currently sits at 70% and this needs to reach 86-90% penetration to achieve the CLF targets outlined in the CP2030 Action Plan.[1,11] However, the National Audit Office estimates that approximately seven million smart meters will need to be upgraded following the phaseout of 2G and 3G; as of early 2026, the vast majority of the 3G network has already been switched off, with expected full retirement of 2G by 2033 at the latest.[9,10,30]

The Market-wide Half-Hourly Settlement (MHHS) is another critical enabler of CLF as it facilitates the availability of more granular data that allows suppliers to send more accurate price signals for demand shifting. The migration of domestic and commercial energy meters to half-hourly metering began in October 2025 and will continue to May 2027, delivered by Elexon, with Ofgem oversight. Considering the importance of MHHS in enabling novel tariff offers and maximising CLF, we are concerned that this deadline is too late and puts the delivery of CP2030 at risk. Through improved accuracy and transparency of energy usage data, Ofgem predict that MHHS, once delivered, will deliver net benefits for GB consumers of between £1.6 billion and £4.5 billion by 2045.[12] Improved data visibility and sharing through a functional data sharing infrastructure (DSI), and enabled by MHHS, opens possibilities for innovative and dynamic consumer tariffs that, in conjunction with automated smart charging, will help boost consumer participation in CLF. NESO is responsible for the delivery of the DSI, including its development, coordination, and governance; given the cross-cutting role of the DSI, it is essential that it is developed with the needs of all users in mind.

Box A: Effective smart meter installation and usage

Effective use of distributed assets that can be used in flex services will require the widespread installation of functioning and future-proofed smart meters, where consumer consent is present for the smooth and unconstrained sharing of household energy use data. According to the NESO Sector Digitalisation Plan, smart meter installation needs to increase from the current 70% coverage to above 86% to unlock the full value of flexibility.[1] Smart meters also need to be operating in smart mode and functioning.

Smart meters must also be replaced and/or future-proofed against the phaseout of 2G and 3G, which will start as early as this year.

There would also be utility in aligning smart meter installation and upgrades with other works where digging up the drive is required such as de-looping (the removal of a shared electricity service cable from two or more properties) or fibre broadband installation. Turning a nuisance for consumers into something that adds value will help with the public acceptance of works associated with the transition.

Dynamic and intelligent flexibility versus TOU peak shifting

Crucially, further digitalisation is essential to dynamically manage peak energy demand and capacity on the LV networks. While participation in non-smart TOU tariffs has had some success at shifting peak demand, analysis by Energy Systems Catapult using data from its Living Lab has found that these tariffs merely shift the peak to the middle of the night rather than resolving the undesirable spike in demand on the network (Figure 1).[31] As electricity demand increases, the size of this new peak will further increase, exacerbating the issue. To avoid this, digital solutions, effective system signals, and data sharing are needed to provide the capability to dynamically stagger usage, through both turn up and turn down of millions of domestic assets and allow for a much more efficient fine-tuning of the system. Without this capability, greater network investment is required to counter the pressure on grid capacity.

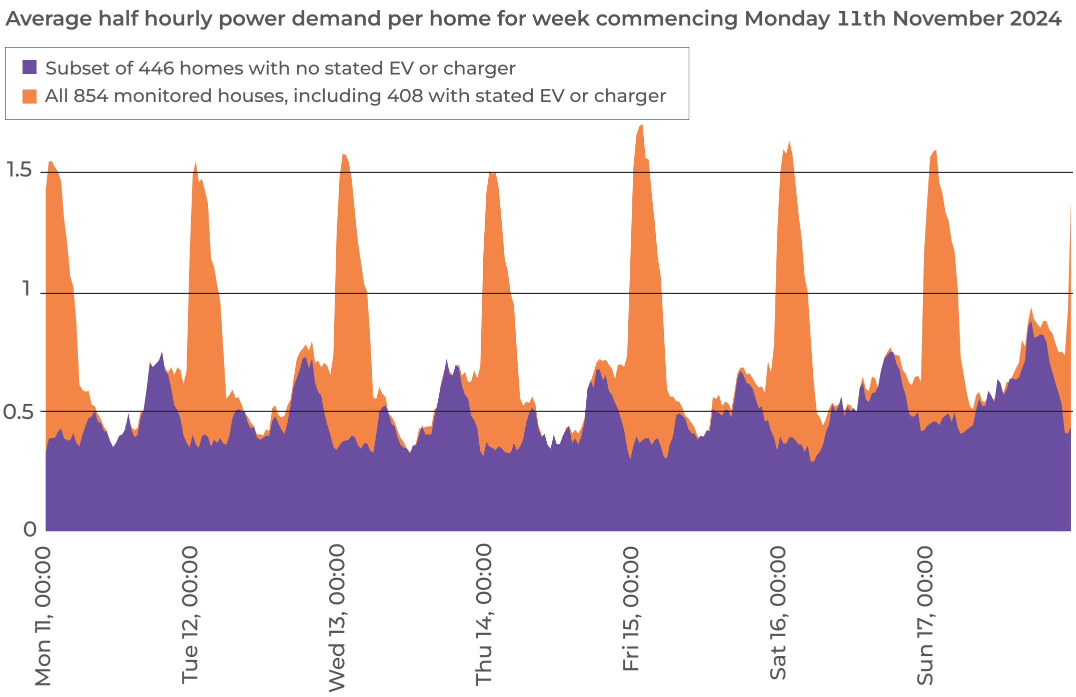

Figure 1: Energy Systems Catapult Living Lab data looking at 408 EV-owning households on TOU tariffs. This illustrates simple peak shifting from normal daytime peak demand. Rather than resolve the peak, it shifts it to a different part of the day.[31]

Turn down events, where consumers can choose to reduce their energy usage at peak times, are already being trialled to help balance network capacity. Through NESO's Demand Flexibility Service, consumers who pre-registered to participate reduced consumption by 3.9 GWh in the winter of 2024/25 and shifted a further ~1.5 GWh.[6,32,33] Through increased digitalisation, rapid data sharing, and connectivity of the system, both turn down and turn up signals (where consumers increase their usage when energy is plentiful) can be more effectively utilised. The digitalisation enablers of turn up and turn down events and their desired outcomes are depicted in Figure 2.

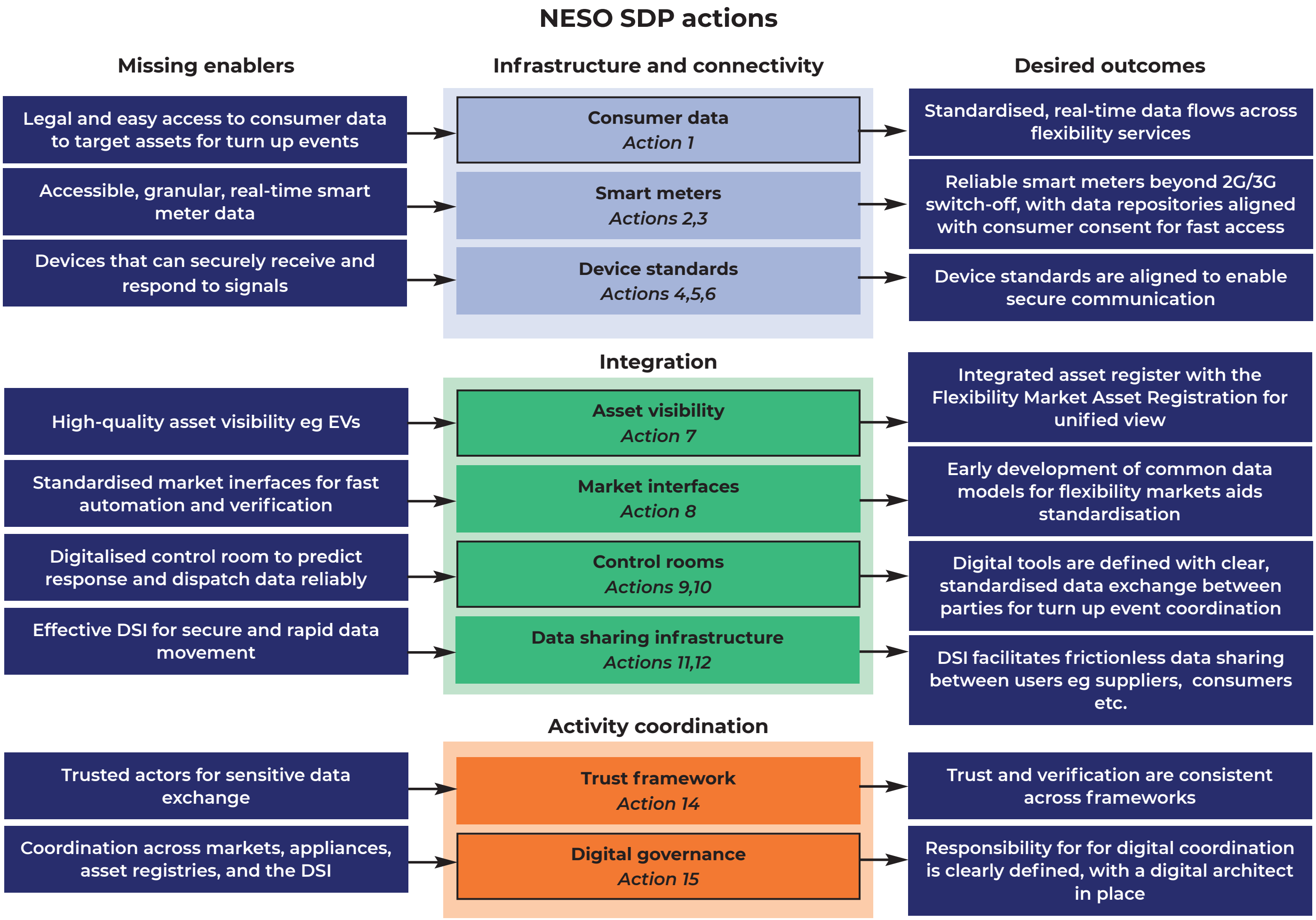

Figure 2: Schematic depicting the missing enablers required to maximise the potential of demand turn up/ turn down events, mapped to actions from NESO's Sector Digitalisation Plan, with desired outcomes from these actions.1 Outlined actions are essential in the short term for successful delivery.

Energy demand is highly spatially heterogeneous, with demand concentrated in the South of England. At present, the GB electricity system struggles with periods of negative residual demand, where supply exceeds demand in a certain region and the excess cannot be transported elsewhere due to capacity and thermal constraints on the transmission network. Unfortunately, this results in high curtailment costs where offshore wind farms need to be paid to reduce their output and gas-fired power stations are paid to fulfil the extra demand in the South. According to Octopus Energy's 'Wasted Wind Tracker', UK wind curtailment costs reached £1.5 billion in 2025, a 10% increase on the previous monitoring period, with estimates that the annual cost of balancing the system could reach £8 billion by 2030.[4,5] On average, 11.5% of available energy has been curtailed across the fleet since 2023, with the highest figures in Scotland.[34,35]

CLF, powered by digitalisation and connectivity, offers a solution, through the full utilisation of turn up events in regions with excess generation.[36] This cannot be achieved through TOU tariffs alone and requires a series of digitalisation activities to be enabled or unblocked. These are depicted in Figure 2. Without digitalisation, including coordinated management of domestic assets, the network will become increasingly difficult and more expensive to balance. Providing CLF is a complex engineering problem that requires a digital ecosystem capable of handling billions of financial transactions, but with the additional complexity of coordinating operation of smart devices with differing characteristics, while ensuring security, and addressing physical network constraints to achieve a nationally balanced system. This is a complex engineering challenge to digitally architect, design, integrate, and operate.

EVs are particularly valuable for their turn up potential as their charging requirements are so flexible; 4.5 GW of the CP2030 CLF target is expected to be met from smart EV charging (compared to 0.5 GW in 2023).[6] EVs are also already a key component of the net zero transition as part of the effort to decarbonise transport; in this sense, EVs could be considered a 'sunk cost', avoiding the need for additional storage capacity in the system. However, this level of dynamic charging is not possible in the current system due to a lack of interoperability between different vehicles and charge points, along with inadequate data sharing infrastructure to facilitate coordination across multiple assets. The additional friction caused by incompatible software further deters consumers from fully participating in flexibility markets. The rapid and successful delivery of MHHS will be critical to enable real-time asset visibility for this coordination. In addition to this and to maximise the potential of EVs for CLF, the deployment and integration of smart, bidirectional V2X charging technologies must be accelerated, and digitalisation will be critical to achieve this by facilitating real-time operational visibility of data and assets, automated flexibility, rapid data sharing between all users, and coordinated management of millions of distributed assets.

Additionally, Distribution Network Operators (DNOs) have limited access to load profile data at present which limits their ability to manage network headroom and to plan capacity expansions. This is a strong argument for a digitalised system with more seamless data visibility and sharing of granular, real-time data.[15]

Box B: Interoperability of domestic low carbon technologies

Significant numbers of the potential assets that could be used in flexibility services are currently not being utilised due to the barriers or challenges faced by flex aggregators that might want to recruit assets for deployment within flexibility offerings. Barriers to full deployment of the range of assetsinclude technical barriers, customer recruitment and marketing. At present, a customer might beinterested in participating in a flexible tariff but there are often challenges to connecting the asset.For example, many combinations of EV model and home charge points are not interoperable with some of the tariffs on offer. And from a consumer perspective, signing assets up to flex assets is still hard because of interoperability issues amid others. The market requires seamless plug-and-play to really take off. Additionally, the savings per individual asset at the domestic level or customer are low and so the cost-benefit of overcoming the barriers by market operators is low.

Efficient and effective operability between markets and control rooms is also hampered by the visibility of assets (see Box E). Control rooms in both DNOs and at NESO have very limited visibility of the potential available flex, due in part to the lack of integration and information sharing between DSOs and DNOs. DNOs are moving towards buying flex

capacity in progressively shorter periods but progress on this, and the dynamic dispatch of flexibility on short (eg 30-minute notice) timeframes is still slow and patchy.

Integration of different flexibility markets and comprehensive and accessible asset registration are both key barriers to more effective deployment of flex in markets and control rooms. Listing all assets in one place can allow them to be made available to multiple markets. For an efficient system, assets and their flex offering need to be able to be sold into multiple markets. Delivering diverse and efficient consumer-led flexibility requires a system that makes more and more decisions via many more devices and digitalisation, and rapid and secure data sharing is going to be absolutely critical for this new, much more diffuse system.

While Elexon is looking at ways that NESO and DSOs can both use the same flex that is then handed off between them, this is moving quite slowly. Enabling the innovation, development and join up needed to connect this highly complex system requires coherence, clear direction and governance arrangements for where the systems need to get to.

Box C: Interoperability of EVs

The value to the system per individual EV is not large and so it is imperative that as many assets as possible can be deployed in flex markets to aggregate value. To do this, EVs must be available for deployment in every possible revenue stream and have frictionless access to all innovative tariffs. EVs, public charge points and home charge points currently operate using a range of proprietary Application Programme Interfaces (API) (i.e. the software that communicates with the charge point/EV). This software is not standardised and is often specific to the manufacturer (of car or charge point). Public charge points have a set of standards, data use rules and software that are specific to their consumer offering, and then in the case of home charging, the system is setup to work with the specific supplier chosen by the consumer. This diversity in APIs makes it very difficult to innovate in this area. Frictionless use of EV assets requires:

- Alignment: Interoperability between software, hardware, tariffs and data sharing.
- Standards: Development of an API standard that allows for innovation. The PAS 1878 and 1879 standards and the work in Octopus's 'Project Mercury' is progressing, but the process is moving too slowly.
- MHHS: Delivery of Market-wide Half Hourly Settlement (MHHS) by the deadline of May 2027, and sooner if possible. At present it is not clear how much MHHS is being used across the system, but indications suggest that it is low, perhaps 10-20% of the market. Not all smart meters have MHHS functionality, and many suppliers are still settling against the demand profile which is set months in advance and as such is much less agile. Rapid implementation of MHHS will create the incentive for suppliers to create more innovative TOU tariffs alongside flat tariffs. MHHS rollout will mean that suppliers will ultimately be forced to provide MHHS which will require forecasting on a half hourly basis. Critically though, it will create greater situational awareness of the network and forecasting much closer to planned usage unlocking truly dynamic tariffs that can manage demand turn up and turn down in a much more granular way.
- Data sharing: Data sharing is also a constraint. Half-hourly meter data is accessed via the Data Communications Company (DCC). This data access has a cost attached to it that the DCC must pay for. At

present, if an innovator wants to get data from the DCC, they need to pay a fee and business models are not always available to make this viable. The Government could, subject to data privacy safeguards and protections, consider widening access to the data making it open to market players.

- Multi-supplier models: Support for multi-supplier models, where a home can choose one energy supplier for household energy and another energy supplier for EV energy. This could open up models that might include EV charging being included in the mileage of a lease plan as part of the benefits of EV ownership. Multi-supplier models require digitalisation to manage factors such as the allocation of metered demand between different suppliers, which requires clean integration into their billing and back-office systems and dynamic reconciliation between the main MPAN meter and any sub-meters.

There is a risk that these activities, particularly around MHHS implementation, would not be delivered if left to market development alone from a supplier perspective, this generates minimal financial benefits and also requires them to take on balancing risk. Suppliers are not going to sell any more energy as a result of this shift in functionality, and thus at present the business case for a supplier to initiate and develop these processes is very limited which means that they are not well-placed to institute this shift in approach. Similarly, this is not functionality that the consumer is going to demand, so there is a question around where leadership for this type of outcome should come from. The outcomes would, however, benefit the system as a whole, the delivery of the CP2030 target and the ease of use for the consumer. There is therefore a strong case for Government intervention.

The ultimate consumer offer for this is compelling, with wide ranging benefit for technology uptake and aggregate system benefits. Sophisticated digitalisation and interoperability could allow for roaming EV charging across energy networks akin to the way mobile phones roam across telecoms networks. In this scenario, you could plug any EV into any charge point, both domestic and public, and the network would recognise whose EV it is and accrue the charges onto the relevant customer account. While plugged in, the system could also plausibly recognise the amount of battery capacity the EV has and potentially deploy it into the system while plugged in for flexibility services such as system balancing, network services etc, according to the agreements that customer was signed up to.

This would require integration across a number of different organisations and decision makers including NESO, DSOs, suppliers, Elexon, charge point operators, OEMs, load controllers and FSPs. And would need real-time data integration to recognise the EV and incorporate the asset into the relevant balancing units and dispatch.

The result would be a real and significant value proposition to EV drivers, making charging much simpler and creating a plug and play model. A key question is, who would be responsible for setting a challenge like this across the relevant sectors? It will not happen in a piecemeal, market-led way and would need central coordination and signalling through policy directives. One route to achieving such functionality could be through vehicle lease plans that combine energy costs into monthly payments and allow customers to plug in and charge anywhere. This would most likely require a multi-supplier model with frictionless splitting of the meter reading between the home and EV suppliers. Lease plan operators may not come forward with this kind of functionality, due to the complexities of the energy system, where they have limited experience. Such a vision would need to come from the energy system and Government and would require an expanded capacity for business development and design to work alongside management of the system.

2.3. Co-benefits of a digitalised system

Co-benefits of digitalisation:

- Management of an increasingly complex system;
- Enables electrification of other sectors, like heat and transport;
- Increased system resilience and efficiency;
- Reduced costs;
- Increased consumer empowerment and support for the transition.

Managing increased complexity

The clean power system aimed for by 2030 will be significantly more complex than the old system and will comprise millions of decentralised domestic, commercial, and industrial assets that can be harnessed for CLF. The old system was highly linear (Figure 3); fossil fuels were used to generate electricity at large power plants, and this energy was transported over long distances via the high voltage transmission networks stepping down voltage to regional networks from high voltage to the LV distribution network to supply residential and commercial consumers.

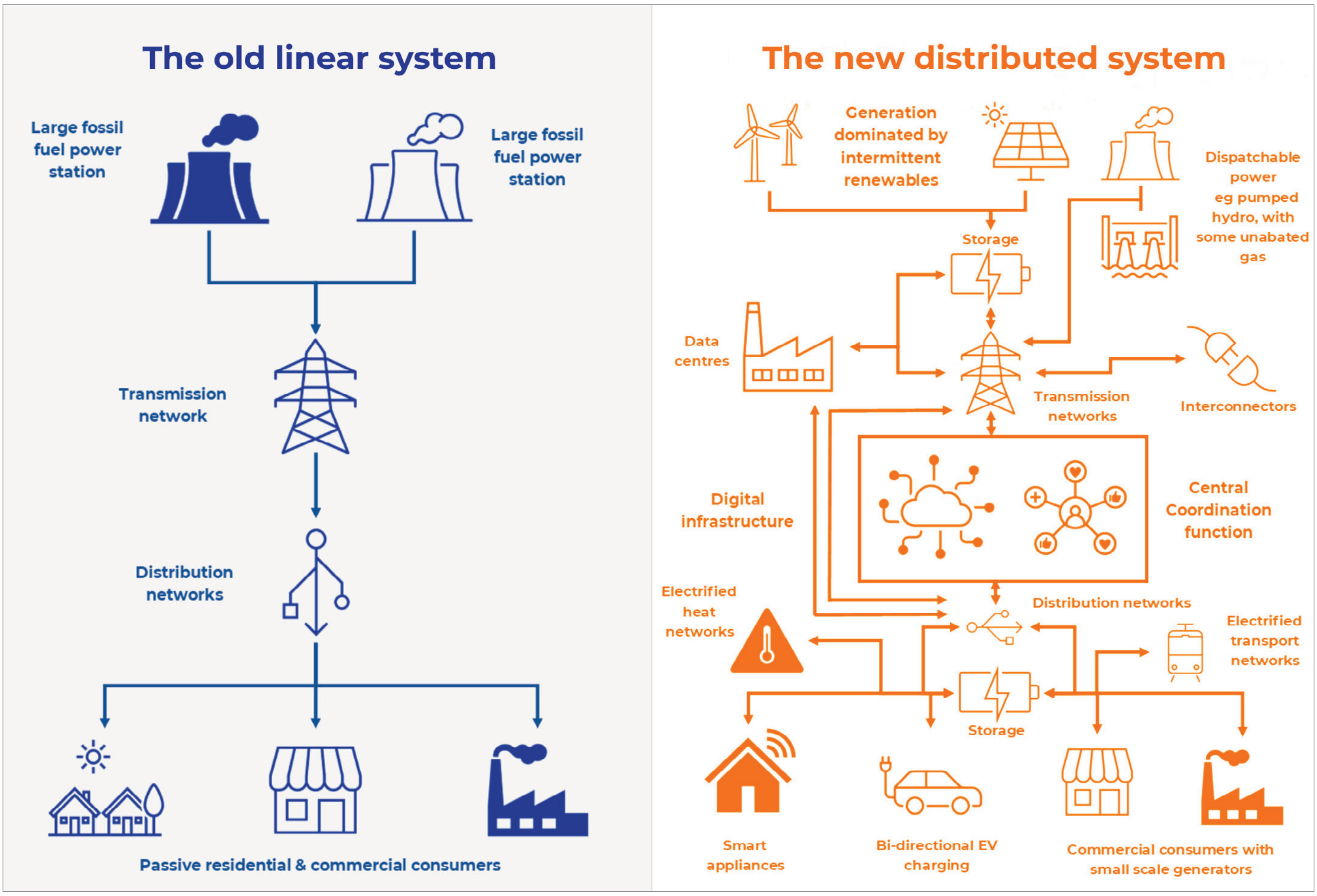

Figure 3: Simplified comparison between the traditional, linear electricity system, and the more distributed and complex system that will exist under a decarbonised electricity system.

Going forward, there is the increased potential for electricity to be generated and supplied directly into the LV distribution networks from small-scale generators like domestic solar panels. The development of V2X technology introduces the possibility of the bi-directional flow of electricity between EV batteries and an individual dwelling or business, meaning EV and household scale batteries will act as sources of both generation and demand.[6]

Digitalisation also helps in the management and connection of multiple assets behind one connection enabling flexibility service providers to fully unlock the potential of CLF. These developments provide numerous opportunities for system flexibility, efficiency, resilience, and innovations in tariff and billing options for consumers but also introduce additional operational complexity that will require real-time data visibility and centralised digital solutions (Figure 2). To fully take advantage of these opportunities, secure and interoperable data exchange between system and market operators and between flexibility service providers and energy consumers and their low-carbon technology assets is key. As discussed later in this report, strong strategic oversight by a digitalisation coordination function, as set out in the DESNZ Energy Digitalisation Framework, will be required to ensure standardisation across markets and to maximise efficiency.[13] The goal of this would not be to centralise system control and data flows, but to set the standards for scaling smart, decentralised operation and control for self-organisation that is responsive to changing energy and system conditions.

As the new system becomes increasingly complex and its control becomes more automated, digitalisation will be essential to help manage complexity and risk; it is important that we understand the state of the system at every point in time, to understand its behaviour and address any emergent behaviours that could put the integrity of the system at risk. Complexity could be managed by ensuring that the visibility of different aspects of the system is available at an appropriate level, rather than overly centralised oversight. This has the potential to bring benefits by reducing redundancies in power networks and margins of error in flexibility procurement. Digital solutions and strong coordination will be key to this.

Box D: Real time system optimisation

System operators currently procure and dispatch flex ahead of time. Given that most customer-led flexibility is stochastic in nature, this means that they must build in some sort of margin of error to account for the likelihood of assets responding. There is then a trade-off between over-procuring (if more assets than expected respond) and the risk of under-delivery (if fewer than expected respond). Real-time visibility into asset state and performance enables this trade-off to be better managed, as the system operators can then tune their dispatch to align to actual asset performance. This maximises the amount of flex that can be delivered from the available assets (as there is less need to build in a margin of error) and minimises the cost of that flex (as no need to pay for flex you don't need). But it is only feasible with well-integrated digitalisation of the assets (and their associated aggregation platforms) and the system operators' control rooms and dispatch platforms.

Enabling the electrification of heat and transport

Electrification of heat and transport is central to the UK's pathway to decarbonisation, as evidenced in the Climate Change Committee's Sixth and Seventh Carbon Budgets.[37,38] The electrification of heat and transport, while already in motion, is expected to grow significantly in the 2030s. More than 473,000 EVs were sold in the UK in 2025, up from approximately 381,000 in 2024, and the planned upcoming ban on the sale of new petrol and diesel cars from 2030 is likely to accelerate uptake.[39,40] The zero emission vehicle (ZEV) mandate, which came into effect in January 2024, specifies the minimum percentage of car manufacturers' sales that must be zero emission, rising from 22% in 2024 (10% of vans), to 80% by 2030 (70% of vans), and 100% by 2035.[41] Meanwhile, the uptake of heat pumps is growing; 42,645 heat pumps were installed in 2024 through government-supported funding compared to 28,084 in 2023.[42] This massive uptick in electricity demand will require significant investment in distribution networks to install the wires and infrastructure needed to support sufficient capacity.

Maximising CLF deployment on the LV networks and laying the groundwork for the oncoming electrification of flexible assets such as heat pumps and EVs will mean that investment is optimised and managed as efficiently as possible as the transport and heating sectors electrify. There remains huge uncertainty in the spatial and temporal trends of low carbon technology uptake, meaning any CLF gains could help mitigate against the risks of this uncertainty. National Infrastructure Commission modelling suggests that between £37 billion and £50 billion of investment will be required by 2050 to ensure the distribution network can handle the electrification of heat, transport, and industry.[15] Ensuring that the adequate digital infrastructure is in place ahead of 2030 will be essential to enable the electrification of these sectors into the 2030s.

Additional benefits of effective data sharing and digitalisation were also set out in the government's Warm Homes Plan policy paper. The paper noted that "data from smart meters could play an important role in helping deliver warmer homes at the lowest possible cost", with plans to introduce secondary legislation in early 2026 requiring heat pumps and electric heating appliances to have smart functionality.[16] To ensure that consumers are engaged in the transition, and that they can access available cost savings via their domestic technologies, the connectivity and data sharing that effective digitalisation enables will be essential.

Increased efficiency and reduced costs

Optimised real-time operability enabled by enhanced data sharing and smart actuation and dispatch will increase efficiency across the entire system, thereby reducing costs. Dynamic management of the system in real-time will also allow for the efficient use of surplus renewable energy across the system via batteries or demand turn up signals. If system management processes can allow for this type of turn up event, there is scope for digitalisation and data sharing to enable a significant reduction in curtailment costs during periods of surplus electricity generation.

In addition to improved energy efficiency through reduced wastage and optimised usage, digital solutions can enhance the efficient use of workforce and materials through better utilisation and strategic sequencing of construction and maintenance of network infrastructure.[43–45] For instance, technologies like artificial intelligence (AI), digital twins, and the Internet of Things (IoT), can help bring predictive maintenance strategies that could bring savings of approximately £5.5 billion by 2030, but they will require a working, digitalised system to be truly beneficial.8 Indeed, the prevailing low uptake of AI in the energy sector can be partially attributed to poor system data accessibility and availability, particularly at the LV level.

With thorough asset registration and seamless data exchange, a greater number of assets will be able to participate in flexibility markets. This is likely to lead to market innovations and make it cheaper for suppliers and network operators to utilise available flexibility due to competitive downward pressure between flexibility aggregators.

Digitalisation and intelligent system management will also help with targeting network reinforcement ahead of time. Significant investment and construction will be needed to upgrade the LV networks connecting domestic dwellings to the grid in order to lay the ground for oncoming electrification. In addition to the investment, this will require widespread coordination of street works and a high number of skilled workers to carry out street-by-street upgrades. Efficient planning and prioritisation of these works will be an important activity and any efficiency gains around load shifting and peak shaving that can be gained at the LV level via digitalisation will help to create more time for planning of these critical upgrade works.

It will be crucial to align device standards and data sharing frameworks to ensure a minimum layer of integration across the system that could expand or shrink as system needs evolve. These interoperability standards need to be established early to cultivate market efficiency gains through economies of standardisation, rather than economies of scale.[1,46] It is important that this design and implementation process is iterative and aims to minimise information redundancies and digital waste that could accumulate if data is not thoughtfully and efficiently utilised.[47] Some progress has been made to define behind-the-meter interoperability standards, but more is needed, in particular to accelerate the development and deployment of interoperability standards in front of the meter. This will enable the large numbers of transactions required across a growing number of flexible assets that will come onto the system and be necessary to enable the electricity networks to run more efficiently and effectively.[48]

Box E: Developing a low carbon technology asset registration system

At present, there is no readily accessible database for registering assets and their relevant specifications, such as EVs and heat pumps that can be used by all relevant parties in the system. Effective asset registration will enable the following things:

- Flex aggregators and those compiling flex services can cross-check that the assets they are stacking and selling match the information and location information they have. This helps with assuring the deliverability of the flex service to the end user which builds confidence in procurement across the wider system.
- It would mean that DNOs have a reliable dataset on the low-carbon assets, such as heat pumps that they have in their network which can then be combined with Flexibility Market Asset Register (FMAR) data to understand how many are participating in flex services. This would enable good visibility and situational awareness for the networks of the number of assets connected to their system, where they are and which are participating in flex services. This will allow for more efficient network investment and upgrade planning. Asset registration also supports DNOs in network planning, assuring security of service and optimising asset life.
- With consumer permission, a Flexibility Service Provider (FSP) can also recruit assets for flexibility services. Recruitment is a significant cost driver for FSPs so giving them access to a comprehensive and clean database of targets could help in reducing their costs and grow the market.

Asset registration is set out as a key enabler in the Sector Digitalisation Plan[1] and the recently-published Energy Digitalisation Framework that assigns Elexon as the domain coordinator for data on ownership and registration data, including asset owner, installer identity and other relevant information.[13] At present there are several asset registers, an effective and functioning asset registration system will need to maintain a single source of truth on asset registration information that is accessible for flex aggregators.

Increased system resilience

At present, the GB energy system is highly exposed to the volatile price of wholesale gas which can negatively impact security of supply owing to the UK's reliance on fossil fuel imports; this particular vulnerability will reduce as fossil fuel generation is reduced and the wider system is electrified.[49,50] Similarly, an increasingly flexible system will help ensure network stability and security of supply.[6] Digitalisation can enhance the resilience of the system further; real-time visibility and enhanced communication across the whole system will mean that thousands of distributed assets can be deployed in real time that can limit the risk of outages and the associated costs to consumers, suppliers, and operators.

It is important that the digital architecture facilitates interoperability and integration across the whole energy system and not just for electricity. There will be considerable interaction with hydrogen, biomethane, and chemical energy storage systems in the future, making seamless integration a necessity to guarantee system resilience.[6,51] Ensuring interoperable digital standards across all vectors will be essential to avoid siloed architectures that undermine wholesystem optimisation and resilience.

Box F: Outage planning and management

Transmission outages required for connecting a new network might take a circuit out for a material period during upgrades. This changes the power flows through the system and adds additional pressure to other circuits. Delivery of the transmission build needed for 2030 will therefore require sophisticated outage planning and coordination of the order and timing according to which certain circuits are taken off and reinstated while ensuring that consumers still have power. Constraint costs may be incurred during an outage due to the reduction in network capacity for generation in some areas. If the system cost is too high to secure the outage, then it can be delayed until system conditions (eg less windy, more optimal outage/generation background), are less onerous but this can lead to congestion and delays in project delivery.[26]

The most efficient and least costly ways to manage outages will require risk mitigation and good situational awareness of the system as well as, where possible, the use of flex to manage ongoing consumer access to power.

If there are assets at affected substations that can serve the load locally, then flex services could be procured and dispatched around planned outages. Additionally, linking data and information about the sites affected by outages to data about vulnerable customers would allow more effective planning and targeting of support, such as customers dependent on electrically operated medical equipment. The current disconnect here is the real-time understanding and situational awareness of the system.

At present, DSOs might plan outages a year ahead, this will not be possible for the pace of the planned transmission and distribution upgrades. A digitalised system with sharing of real-time data, that also supports dynamic use of flex and situational awareness of the system would allow for faster and more efficient outage planning and more flexible and dynamic risk mitigation for outages. This, however, would require effective data collection and sharing between relevant parties and diverse and varied flex packages that can be dispatched at affected substations to mitigate planned outages.

Crucially, effective data sharing and the use of digital solutions in a digitalised system can further enable data-driven decision making to enhance planning and coordination of new distributed assets and grid infrastructure, ensuring that the system aligns geographically with the growth in demand.[1] However, these opportunities can only be realised if the correct data sharing infrastructure and associated governance framework are in place to facilitate the timely sharing of insights between national and regional systems.[52,53] An increasingly digital system is also more at risk of cyberattacks and robust security measures to protect control rooms and data flows are paramount.[54] The benefits of a digitalised system justify the need to find ways to manage these developing risks. Our 2024 report emphasised the need to transform the system to be "digital-first in a cyber-secure way".[14] The NESO Sector Digitalisation Plan includes further details of what this should entail.[1] It is imperative that we sufficiently safeguard the systems that we digitalise.

Box G: Safe system operation and situational awareness

System digitalisation has significant benefits for the DNOs who play a key role in maximising and optimising the work done by the system as effectively as possible, minimising costs and planning the build out of the network when required.

To run the system as efficiently as possible, networks need to know that they are operating the system safely and that requires good situational awareness of what is happening on the network at a granular time resolution. Digitalisation and data sharing on networks (and the monitoring of assets that this enables) are critical to the provision of situational awareness for safe operation of the network i.e. to know that they are operating the system within system limits.

Some DNOs have created digital twins of their networks that is allowing them to work their networks harder and drive efficiencies to better predict, identify and fix faults, thereby creating cost savings and the need to build less network. It should also provide predictive capability to plan investments better – knowing how much network you're using can help in planning the network better.

If network digital twins can morph into system digital twins (ie including data relating to electrical assets in the hands of other parties, such as consumers and generators) then we would have an integrated and highly granular understanding of opportunity and risk that would be game changing. It would allow us to spend less by using assets to the maximum, and to bring entirely new ways of looking at both consumer propositions and system challenges. In the future, those system digital twins could then be connected to other insights, such as hyperlocal weather patterns, traffic flows, local air quality and the like. The latter would need to happen under longer timelines but would require the underlying architectures and ontologies to be right at the outset.

However, the networks are at different stages in this digitalisation process and more coherent progress on digitalisation across the networks would benefit from policy and regulatory incentives to invest in digitalisation and the design and implementation of common standards.

Consumer empowerment and participation

One of the major benefits of digitalisation of the electricity system is the ability to provide as much simplicity as possible to consumers. In the old system, consumers were passive entities, but the clean power transition will transform their assets into active participants in the flexibility market. Consumers are also active stakeholders in the clean power transition itself. Fundamentally, one of the greatest risks to the delivery of CP2030 is a lack of public buy-in and support for this system-level transformation; we need to bring the consumer with us on this transition for it to be successful. In this sense, the delivery of digitalisation and greatest simplicity for consumers becomes a particularly politically salient issue.

"Smart technology and a digitalised system will further empower consumers" [16]
Warm Homes Plan, 2026

Smart appliances, smart charging, and smart meters all empower consumers to make more informed decisions about their energy usage, particularly through participation in flexibility markets. NESO's Crowdflex trial found that TOU tariffs can help consumers reduce their evening peak demand by up to 23%, with subsequent cost savings.[28,29] As mentioned, digitalisation also offers opportunities for innovative tariff options, and these could be structured in a way to tackle energy poverty.[55] However, digital inclusion must be a central pillar of the transition to avoid deepening inequalities.[56–58] It is essential that the future energy system offers good, digitally-enabled consumer experiences and prioritises the need to avoid marginalisation and digital exclusion.

Digitalisation is also an enabler of new consumer products and offerings that are yet to be conceived. From the perspective of energy suppliers, digitalisation offers opportunities for improved understanding of consumer behaviour which ultimately could improve their service offerings, and the contributions they make to supply security, affordability, and carbon intensity. However, consumers first need to trust that their data is being used safely and securely, with effective consumer consent frameworks in place.[59,60] In addition to initial consumer consent, ongoing trust frameworks and agreements between all actors will be required to streamline the process of data exchange and avoid the need for repeated individual credit checks. Digital contracts will also be required between all parties to enable the high volume of transactions that will be needed to take place smoothly. Data verification processes will need to be robust to ensure data is portable across the digital ecosystem.

Box H: Consumer consent

Consumer consent for data sharing in the electricity system is critical to many aspects of digitalisation to ensure the sharing and free movement of data across the system. Consumer consent around smart meter data is a particularly critical challenge to overcome to enable the full suite of flex products onto the market. At the moment, many aggregators are working with data from asset meters that are located at point of use, rather than being an aggregate of home usage. To use and handle the data from smart meters, consumer consent is required and at present there is a tendency for data to not be shared due to risks and concerns around data protection. Without voluntary consumer consent, data sharing will be inherently more complex and riskier.

RECCo, with oversight from Ofgem, are developing a consumer consent mechanism and to detail requirements and a design for the consumer consent service. This is due by the end of 2026 to align with the delivery timescales of MHHS but will need to be driven with urgency and pace thereafter.

3. Lessons from France: a case study of digitalisation

Through collaboration with the National Academy of Technologies of France (NATF) in 2025, the Royal Academy of Engineering has gained valuable insights into the electricity system in France and the benefits they have reaped from embedding digitalisation and data-sharing across the system.

France has a much higher penetration of smart meters across the country; 96% of customers were connected in 2025, compared to 70% in the UK.[11] Unlike the UK roll-out, which operated as an opt-in process, the roll out of smart meters in France was effectively mandatory, with fines beginning in January 2023 for households that refused installation. Context is crucial here; 95% of the distribution network of France, including Paris, is operated by a single network operator, ENEDIS, compared to six operators in the UK. The network operator was also responsible for smart meter rollout in France, as opposed to suppliers. The French energy mix is also different, with their nuclear fleet generating 65% of their total electricity output by 2023. However, despite the contextual differences, the French electricity landscape offers some valuable lessons and highlights the potential opportunities from increased digitalisation of the GB system.

Smart meters enable real-time monitoring of energy usage so that consumers can make informed decisions about their consumption and network operators can manage supply and demand across connected assets like EVs and heat pumps. In France, the network of smart meters has enabled 4G and power line carrier communication between the distribution system operator (ENEDIS) and consumers, facilitating remote control of EV charge points and remote detection of faults on the LV network. They have installed digital remote-controlled switches on the medium voltage network and smart substations at low and medium voltage. As such, system management is more efficient. AI has been utilised to optimise repair and maintenance; they are able to calculate the potential for failure on different parts of the subsurface cable network and make targeted replacements, which they did ahead of the 2024 Paris Olympics.

At present in the UK, network operators only have access to aggregated smart meter data, which restricts the possible uses. While smart substations have been trialled at some UK DNOs, the technical support required was deemed too expensive to continue at such small scale. Digitalisation is a key enabler of economies of scale, which is crucial to any large deployment of new technology. By making network operators trusted users with access to more granular smart meter data, there could be better situational awareness of the system, enabling better planning and optimising system management. The digitalisation of France's energy system is therefore a useful case study into the potential benefits of a more comprehensive digitalisation strategy in the UK.

ENEDIS electric utility van on site in a domestic setting, France. *Photo: Shutterstock*

4. The digitalisation coordination function

Despite multiple parallel initiatives, the UK currently lacks a designated authority for nationwide digital architecture, governance, and integration. The result is fragmented efforts, duplicated activity, and technical divergence across the system. An effective coordination function is essential to:

- **Define systemwide rules, standards, and interfaces;**
- **Ensure interoperability and prevent technical lock-in;**
- **Align delivery timelines and functional dependencies;**
- **Provide a reference framework for innovators and delivery bodies;**
- **Support whole-system planning across data sharing, cybersecurity, and market design.**

4.1. Why is a digitalisation coordination function needed?

The government's Clean Flexibility Roadmap noted that:

"Strategic direction needs to be provided across the whole digitalisation landscape, underpinned with common tools, architecture and approaches. Coordination and governance of the different owners of key digital infrastructure through a clear governance framework is critical so that the different initiatives are designed for interoperability and avoid duplication" [6]

At present, there is no designated body who has overall responsibility and ownership of architectural governance and coordination of a nationwide digitalisation strategy. Instead, our ongoing sector engagement suggests that roles and responsibilities are confused and disconnected between multiple actors; there is confusion over who has ownership of the digitalisation policy area and there is no coherent oversight framework. This lack of clarity and direction is impeding progress towards CP2030 and the benefits detailed thus far and, worse, risks the delivery of systems that fail to integrate. The sector has reached an inflection point where the absence of coordinated architecture will lead not only to technical divergence, integration failures, and cybersecurity vulnerabilities, but also to misaligned business processes, inefficient workflows, and fragmented service delivery. This is where a digitalisation coordination function is needed.

Ofgem and DESNZ have made a good step forward by outlining the responsibilities and governance structure of digitalisation in the recent Energy Digitalisation Framework, but further work is needed to ensure alignment between domain coordinators and to create an effective, permanent digitalisation coordination function.[13]

4.2. What does digitalisation coordination look like?

The starting point for digitalisation coordination should be a focus on delivering good outcomes for consumers and citizens. The digitalisation coordination function does not designate the desired policy direction or outcomes of the system; the coordination function's role is focused on the 'how' of delivery and in designing the architecture that will deliver the designed outcomes, including outlining its scope, requirements, components and actors, and the points of interaction in the system. Such an architectural framework should sit alongside a roadmap that details key milestones with increasing room for adaptation and review further along the road so that new capabilities and emerging developments can be accommodated. By this, we mean a roadmap that fits the definition in Box I that goes beyond the existing Clean Flexibility Roadmap to cover the aspects of digitalisation described in this report and with ambitious timeframes for the acceleration of digitalisation. Together, the system architecture and roadmap provide the framing needed to support implementation and ensure that the decisions of various delivery parties integrate and complement each other. In addition to this, it would be useful to prepare a landscape document that sets out the current state of digitalisation (Box I).

Box I: Definitions

Roadmap: **provides the temporal perspective on the architecture and how it will be realised over time through a series of milestones that introduce new capabilities and maintain, enhance or retire existing capabilities. It is managed to be adaptive to change across the system.**

Landscape: **describes the state of digitalisation, including the work that is underway, committed, or planned, and how the various initiatives relate to each other. It reveals gaps and points of duplication. It provides a reference to be used by all stakeholders to discuss energy system digitalisation, knowing that they are speaking in a shared language.**

This distinction is crucial; the architecture is a tool to guide delivery bodies and should exist as a live resource that is managed and updated by the digitalisation coordination function. A system integrator should work with the digitalisation coordination function to deliver the vision of the digital architecture and ensure that all components come together to form an energy system that works and is on time and on budget. To illustrate, when someone wants a new house, they would employ an architect to translate the living experience they want (the outcomes – in this case, a digitalised energy system) into a design for a house (the architecture) and a builder (the system integrator) will construct it and employ specialists such as electricians and carpenters (the systems and component developers) to deliver the architect's vision. Each of these roles are needed to deliver digitalisation, but these roles are currently poorly defined.

The energy system is extremely complex and will become more so. It is a system-of-systems where multiple component systems exchange data, share processes, and rely on each other's functionalities to operate correctly. These interdependencies are depicted in Figure 4.

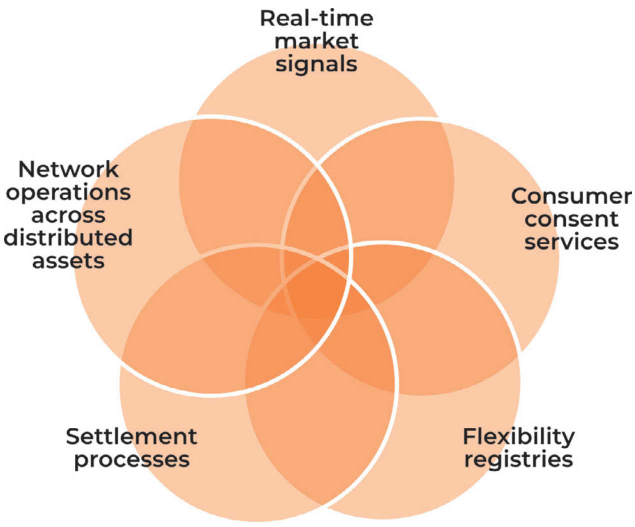

Figure 4: Interdependencies within the energy system

The digitalisation coordination function must consider these interdependencies and manage the trade-offs as they evolve over time. As such, digitalisation coordination should be applied where it is needed to:

- Align stakeholder efforts and avoid unnecessary duplication;
- Identify functional and timing gaps;
- Achieve an integrated, working system by aligning the availability of needed components and the interfaces that allow them to interact via the thousands of distributed assets;
- Deliver interoperability across system processes, components, market mechanisms, and actors;
- Prevent technical divergence and reduce lifecycle costs e.g. prevent installation of smart meters that rely on 2G/3G mobile networks;
- Reduce integration overheads by enabling reuse of common components and processes;
- Support the integration, enhancement, or retirement of legacy systems as the architecture and roadmap evolve;
- Provide a reference point platform for innovation;
- Reduce the risk of commercial capture by facilitating active solution building across multiple parties;
- Support whole-system planning and optimisation;
- Ensure current design choices do not constrain future capabilities, such as embedding SMETS 1 and 2 smart meters that would constrain delivery of key components of CP2030.

Rather than 'owning' the individual systems, the digitalisation coordination function should set the rules, frameworks, and design standards that ensure that every digital component of the energy system can connect, exchange data, interact effectively, and evolve safely and efficiently. One approach would be to consider coordination as a spectrum of authority relationships where some activities are centrally directed, others more collaborative, and some are executed through influence. As ever, the focus should be on consumer needs and the delivery of services that effectively meet these needs.

Figure 5 illustrates the responsibilities of the coordination function. In addition to designing the digital architecture of the emerging energy system that takes all stakeholder perspectives into account, the digitalisation coordination function should develop, share, and where needed, mandate the design principles, rules, and standards needed across the ecosystem to ensure data sharing, standardisation, and interoperability across sectors. These standards should include principles for:

- Data sharing inf rastructure;
- Privacy by design;
- Security, resilience, auditability, and efficiency standards;
- Version-controlled interface approaches and capabilities for process automation and technical integration;
- Shared data models and ontologies that encourage a shared language.

These system Application Programming Interfaces (APIs), data standards, and digital infrastructure components should be catalogued in an open and transparent way to help align delivery bodies and give innovators clear guidance on how to connect to the system. Furthermore, the digitalisation coordination function should design and distribute the mechanisms for assurance and compliance with the digital architecture they develop, with structures in place for participating entities, including consumers and market innovators, to feed insights and challenges back into the architecture.

As part of the digitalisation coordination function, it will be important to have a clear evidence-based assessment of which datasets are most urgent. This should then inform which ones should be prioritised for the development of standards. For example, all the types of data listed in the Energy Digitalisation Framework under the 'Behind-the-meter asset domain' in Section 6 are critical to the delivery of CLF – a clear priority. These include asset data and technical specifications, locational data, ownership of asset data, and operational data such as usage profiles and demand response capability. A minimum viable plan for what is needed to de-risk delivery of CP2030 is urgently required to provide impetus around a realistic starting point. This can then further be expanded and optimised over time.

In their Energy Digitalisation Framework, DESNZ and Ofgem commit to consulting on the options for a digitalisation coordination function by the end of 2026, and we welcome this announcement. Three potential approaches, set out below, deserve consideration.

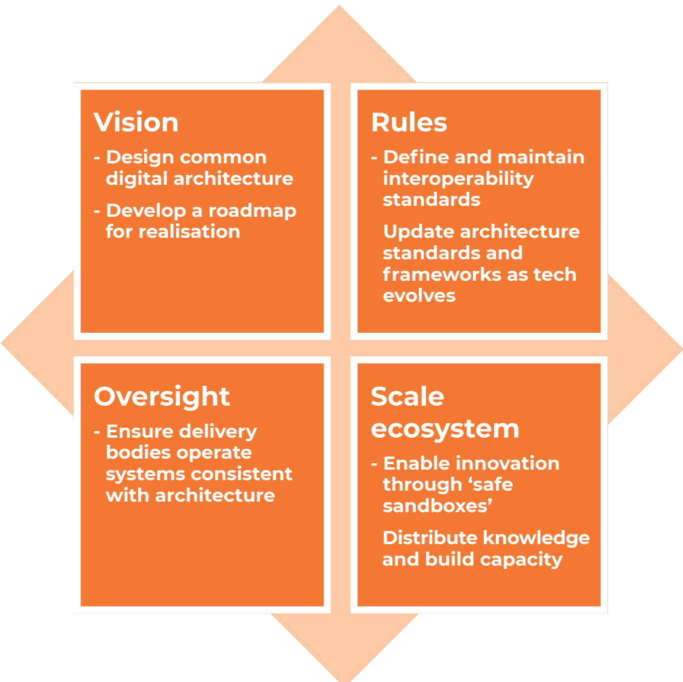

Figure 5: Key functions of the digitalisation coordination function for the GB electricity system

Approach 1: A NESO-hosted function

In this approach, the coordination function would sit within NESO but be governed by Ofgem and DESNZ. Here, NESO would be neutral, with a mandate to ensure coherence across all digital delivery bodies and develop the common digital architecture. Independent advisory boards would ensure transparency and inclusion of diverse perspectives.

This approach builds on NESO's position in providing the Sector Digitalisation Plan and its stated commitment to its ongoing development. Importantly, it also offers direct connection to energy system planning, already a NESO responsibility, reducing the risks that can arise through distance or imperfect interfaces with other organisations. We note that NESO fulfils multiple roles in the energy sector including system operator, strategic system planner, and solutions developer. As such, this approach would require strong governance to avoid real or perceived bias in decision making. This should be achievable but would need to be mindful of delivery and decision-making timelines and the need for pace.

Approach 2: An independent expert entity

In this approach, the coordination function would be a newly formed body created through collaboration between Ofgem, DESNZ, and industry. The new entity could provide strategic coordination, architectural oversight, and convening power without operational delivery. While such a body would be neutral and have cross-sector reach, it would likely be slow to establish and would require joint funding and possible legislation. Explicit effort would also be required to ensure the digital architecture aligns with energy system planning.

Approach 3: A federated model

In this approach, the coordination function would be a shared responsibility across existing bodies with a 'coordination forum' chaired by Ofgem or

DESNZ. Here, each body would retain ownership over digital architecture within its own domain, such as system operation or metering, but with alignment via common principles, reference models, and shared governance. An advantage of this approach is that it builds on existing structures, but it would be harder to enforce and risks continued fragmentation. There is also a risk that such a model would not be considered to have sufficient authority to drive delivery and could be perceived as an advisory function rather than an official digitalisation coordination function.

In their Energy Digitalisation Framework, DESNZ and Ofgem outline a near-term proposal that is aligned with a federated approach, but clarity on the longer-term approach is critical.

Other approaches are possible and should be explored. In any case, it is crucial that a permanent digitalisation coordination function is developed rapidly and embedded within the energy system. As NESO has responsibility for energy system planning, separating the two functions could risk misalignment and sub-optimal system integration. Investment in people and skills would be required to enable NESO to fulfil such a role, alongside collaboration with external experts and stakeholders.

Digitalisation coordination will be an ongoing challenge that will evolve as the digital strategy matures. Temporary or short-term governance would merely be a sticking plaster; responsibility for ongoing architectural governance should reside with a permanent authority empowered to maintain coherence as a fundamental attribute of digitalisation of the energy system. It is important that timelines for the establishment of a permanent coordination function, digitalisation architecture, and comprehensive delivery plan are not permitted to drift. The DESNZ Energy Digitalisation Framework states that the process of setting up the permanent coordination function will take two to three years, thus potentially taking until 2029.[13] This slow pace is concerning, as is the lack of committed timelines beyond the end of the calendar year.

Technicians discussing operations at Barry Power Station, Wales, UK. *Photo: Alamy*

5. Our recommendations

Establishing a dedicated digitalisation coordination function will be essential to realise the potential of digitalisation of the electricity system. We strongly support efforts to establish such a function and look forward to supporting Ofgem and DESNZ to implement the needed capability to achieve this.

A digitalisation coordination function and a system integrator will be necessary to minimise delays, constrain costs, and ensure the evolving system is fit for the future. Without sufficient coordination or urgency, we risk jeopardising central components of the CP2030 target, including:

- 10 GW to 12 GW of consumer-led flexibility;
- An extra 19 TWh per year in demand from the electrification of other sectors, including heat and transport.

If we fail to meet these targets, we also risk failure to meet other net zero commitments,[61] such as the UK's legally binding commitment to reach net zero greenhouse gas emissions by 2050 under the Climate Change Act 2008.[37,38,62]

Therefore, we call on government to prioritise digitalisation as a matter of urgency and make the following recommendations:

Urgently establish a permanent digitalisation coordination function as envisaged in the recently published Energy Digitalisation Framework. The government should confirm that the architecture to be prepared within the digitalisation coordination function will be supported by a digitalisation landscape and roadmap.

Ensure that the digitalisation coordination function has the capability to ensure delivery of systems and solutions that conform to the architecture, and mitigate risk, acknowledging that many parties will contribute to delivery. These parties will include those providing shared infrastructure and those providing innovative competitive services.

Establish a system integration function, that works closely with, or as part of, the digitalisation coordination function to ensure that systems and solutions work across the evolving energy system.

Clarify policy ownership for all aspects of digitalisation and establish dedicated oversight for each issue within central government.

Implement feedback loops that inform and enable change. Continuously monitor, capture, and learn from real time activity and explicitly feed this learning into improvement and evolution measures for all parties.

Use NESO's Sector Digitalisation Plan as a basis for near-term actions and identification of gaps in oversight and delivery.[1] This document is a good starting point, but the actions and focus areas identified need to be actively managed if they are to be useful.

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References

1. NESO. (2025). *Energy Sector Digitalisation Plan—The digitalisation actions needed for Clean Power 2030.*
2. NESO. (2024). *Clean Power 2030: Advice on achieving clean power for Great Britain by 2030.*
3. *Clean Power 2030 Action Plan: A New Era of Clean Electricity.* (2024). Department for Energy Security and Net Zero.
4. NESO. (2025). 2025 *Annual Balancing Costs Report*. NESO.
5. Octopus Energy. (2025). *Wasted Wind Tracker.* Wasted Wind.
6. DESNZ, Ofgem, & NESO. (2025). *Clean Flexibility Roadmap*. UK Government.
7. DESNZ. (2024). *Future default tariffs: Call for evidence*. DESNZ.
8. Caspian Conran & Maddy Binns. (2025, June 5). Speeding the shift while saving millions: Digital tech's economic impact on the energy transition. *Baringa.*
9. Tudball, M. (2026). *Smart meters (Rapid Response No. RR88).* UK Parliamentary Office of Science and Technology (POST).
10. House of Commons Committee of Public Accounts. (2023). *Update on the rollout of smart meters: Seventy-Second Report of Session 2022-23*. House of Commons.
11. *Smart Meter Statistics in Great Britain: Quarterly Report to end September 2025.* (2025). DESNZ.
12. Ofgem. (2021). *Market-wide Half-Hourly Settlement: Final Impact Assessment*. Ofgem.
13. Ofgem. (2026). *Energy Digitalisation Framework: A vision for a coordinated and connected energy system*. UK Government.
14. *Rapid Decarbonisation of the GB Electricity System*. (2024). Royal Academy of Engineering.
15. NIC. (2025). *Electricity distribution networks: Creating capacity for the future.*
16. DESNZ. (2026). *Warm Homes Report*. UK Government.
17. *Data Sharing Infrastructure (DSI) | National Energy System Operator.* (n.d.). Retrieved 13 April 2026.
18. DBT. (2025). *The UK's Modern Industrial Strategy*. UK Government.
19. Stream. (n.d.). *Stream—Portal.* Retrieved 13 April 2026.
20. DEFRA. (2023). *Defra digital and data transformation strategy 2023 to 2030.*
21. Qadrdan, M., Hawker, G., & Heptonstall, P. (2025). *Flexibility in the GB Power System: Future needs, alternative sources and procurement*. UK Energy Research Centre (UKERC).
22. Jennings, Z. (2024, November 1). *Carbon emissions reduced by batteries in Great Britain—Research.* Modo Energy.
23. IEA. (2025). The Value of Demand Flexibility.
24. LCP Delta. (2026). *From bottlenecks to balance: Impact of Reformed National Pricing measures on GB grid constraint costs*. LCP Delta.
25. BEIS. (2021). *Smart systems and flexibility plan 2021: Appendix I - Electricity system flexibility modelling*. UK Government.

26. DESNZ. (2023). *Accelerating electricity transmission network deployment: Electricity Networks Commissioner's recommendations.* UK Government.

27. Ørsted. (2025, May 7). *Ørsted to discontinue the Hornsea 4 offshore wind project in its current form.* Ørsted.

28. NESO. (2025). *CrowdFlex Report: Utilisation Trial Winter 2025*. NESO.

29. NESO. (2025). *CrowdFlex Report: Availability Trial Winter 2025*. NESO.

30. Clark, A. (2024). *Switching off 2G and 3G in the UK* [Research Briefing]. Parliamentary Office of Science and Technology.

31. Claire Rowland. (2025, June 25). The emerging EV overnight demand peak. *Energy Systems Catapult.*

32. NESO. (2025). *Demand Flexibility Service: Evolution Update*. NESO.

33. NESO. (2025). *Demand Flexibility Service: Winter 24/25 Overview Report*. NESO.

34 Callum MacIver & Keith Bell. (2025, June 16). *Transmission Network Unavailability – the Quiet Driving Force Behind Rising Curtailment Costs in Great Britain.* UKERC.

35. Blyth, W., Gross, R., Heptonstall, P., MacIver, C., & Jamieson, M. (2025). *Zonal Pricing, Volume Risk and the 2030 Clean Power Target*. UKERC.

36. Torriti, J. (2026). Demand turn-up in electricity markets: Economic lessons f rom non-energy sectors. *Energy Research & Social Science, 135*, 104664.

37. CCC. (2020). *The Sixth Carbon Budget: The UK's path to Net Zero*. Climate Change Committee.

38. CCC. (2025). *The Seventh Carbon Budget*. Climate Change Committee.

39. DfT. (2025). *Phasing out sales of new petrol and diesel cars from 2030 and supporting the ZEV transition: Summary of responses and joint government response.* Department for Transport.

40. Zapmap. (2026, February 13). *EV market statistics 2026: Tracking the growth in EV sales in the UK over time.*

41. DfT. (2025, January 6). *Phasing out the sale of new petrol and diesel cars from 2030 and support for zero emission vehicle (ZEV) transition.* GOV.UK.

42. *Heat pump deployment statistics: December 2024.* (2025). DESNZ.

43. Stricker, N., Egetenmayer, S., Gerstmeier, F., Strack, C., & Streinz, F. (2022). Current role of the digital transformation for improved materials and material utilization. *Procedia CIRP, 10th CIRP Global Web Conference – Material Aspects of Manufacturing Processes*, 115, 60–65.

44. Topic, M., & Biedermann, H. (2020). Increasing Resource Efficiency Through Digitalization – Chances and Challenges for Manufacturing Industries. In Z. Anisic, B. Lalic, & D. Gracanin (Eds), *Proceedings on 25th International Joint Conference on Industrial Engineering and Operations Management – IJCIEOM* (pp. 1–11). Springer International Publishing.

45. Barteková, E., & Börkey, P. (2022). Digitalisation for the transition to a resource efficient and circular economy. *OECD Environment Working Papers.*

46. Rolando Fuentes & Bassam Fattouh. (2023). *The implications of digitalization on future electricity market design* (Energy Insight 128). The Oxford Instutute for Energy Studies.

47. Iheacho, C. (2025, April 4). Digital waste tracking: A hidden component of sustainability. *Institute of Sustainability Studies.*

48. Connectivity Standards Alliance. (n.d.). Build With Matter | Smart Home Device Solution. CSA-IOT. Retrieved 24 April 2026.

49. Zakeri, B., Staffell, I., Dodds, P. E., Grubb, M., Ekins, P., Jääskeläinen, J., Cross, S., Helin, K., & Castagneto Gissey, G. (2023). The role of natural gas in setting electricity prices in Europe. Energy Reports, 10, 2778–2792.

50. Evans, S., & Lempriere, M. (2025, May 20). Factcheck: Why expensive gas – not net-zero – is keeping UK electricity prices so high. Carbon Brief.

51. Johnson, N., Liebreich, M., Kammen, D. M., Ekins, P., McKenna, R., & Staffell, I. (2025). Realistic roles for hydrogen in the future energy transition. Nature Reviews Clean Technology, 1(5), 351–371.

52. Ofgem. (2024). *Governance of a Data Sharing Infrastructure*. Ofgem.

53. Li, F., Turvey ,N., Dale ,L., Scott, J., Padget, J., Flower, I., Fitzpatrick, J. R., Ostler, N., Oldaker, R., & Yeo, S. (2025). Do we need a data sharing infrastructure for the energy sector? IET Smart Grid, 8 (1), e12196.

54. International Energy Agency. (2021). Enhancing Cyber Resilience in Electricity Systems. OECD.

55. Gavin Lee & Nikki Sutherland. (2025). *Debate on consumer-led flexibility for a just transition* [Debate Pack]. House of Commons Library.

56. Joesph Chambers, Caitlin Robinson, & Matthew Scott. (2022). *Digital inclusion in the energy system: How do we ensure the opportunities and benefits of digitalisation can be accessed by everyone?* (Policy Briefing 121). Policy Bristol, University of Bristol.

57. Pilatin, A., Radulescu, M., Alofaysan, H., Barut, A., & Huseynova, R. (2025). Smart Solutions for Sustainable Access and Technological Equity: The Effect of Energy Transition, Artificial Intelligence, and Digital Economy on Energy Poverty. Geological Journal, n/a (n/a).

58. Centre for Sustainable Energy. (2024). *Understanding the barriers and enablers to supporting fuel poor households achieve net zero*. Committee on Fuel Poverty.

59. Ofgem. (2023). *Data Sharing in a Digital Future: Consumer Consent* [Call for Input].

60. Ofgem. (2025). *Consumer Consent Decision*. Ofgem.

61. Nuala Burnett, Iona Stewart, & Thomas Hewitt. (2025). *The UK's Plans and Progress to Reach Net Zero by 2050* (No. 9888 Research Briefing). House of Commons Library.

62. Committee on Climate Change.(2015). *The Fifth Carbon Budget*.

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